OPERATIONS ANALYSIS OFFICE

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EVAPORATION LOSSES RESULTING FROM
CAMOUFLAGE OF POL TANKS IN KOREA,

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SUMMARY

At the present time, POL tanks in Korea are painted white to minimize evaporation losses. This makes them highly visible to potential attacking aircraft. If the POL tanks are painted with a dull tonedown color similar to that being accomplished for the remainder of the air base facilities, there is the concern that evaporation losses might be costly. This paper determines the cost of POL evaporation associated with tonedown painting of tanks and explores several alternatives.

At Kunsan and Osan Air Bases, there are eight principal POL tanks aboveground. If these tanks were painted with tonedown colors, total evaporation loss cost for all of them together would increase by about $2000 per year. Two alternatives that reduce the evaporation losses even more and additionally provide concealment superior to tonedown painting are burial and camouflage with netting. Either of these alternatives would reduce evaporation losses more than the $2000 per year; but in neither case would this saving offset the increased installation costs.

Since gasoline storage suffers nearly four times greater evaporation losses, as compared with JP-4, the recommendation is made that gasoline be stored underground whenever this option is available and tactical considerations permit it. Floating pans also reduce the evaporation losses significantly; and even though not cost-effective to install on existing tanks, priority should be given to storing gasoline in these tanks.

Several of PACAF present policies were affirmed in this study. PACAF's full tank policy results in minimum evaporation loss. Constructing new tanks underground also results in minimum evaporation loss.

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Tables and Figures

1. BACKGROUND AND OBJECTIVE. Pending an XOA study of tonedown effectiveness in Korea, HQ PACAF in May 1974 directed interim tonedown of USAF facilities on Korean bases with "solid, dull/flat colors to match the predominant seasonal color of the year." Implementation of the interim tonedown policy is to occur during the normal repainting cycle commencing FY 76. Because of concern over possible increased evaporation losses from darker colored tanks, hitherto painted white, the interim policy specifies that camouflage nets, rather than tonedown paints, will be used for aboveground POL tanks. The objective of this study was to determine if the cost of POL evaporation resulting from use of darker paint on tanks is such as to justify alternate camouflage methods (e.g., netting) from a strictly economic standpoint. Considerations of increased camouflage effectiveness which may be afforded by such alternate methods were not evaluated.

2. METHODOLOGY

a. This study relies primarily upon an internal publication by SOCAL (formerly Standard Oil Company of California) entitled Evaporation Prevention Manual (ref 1) which, in turn, is largely based upon several American Petroleum Institute (API) evaporation loss bulletins, the most pertinent of which is API Bulletin 2518: Evaporation Loss From Fixed-Roof Tanks (ref 2). Three categories of evaporation losses are considered in the manual: boiling losses; working losses; and breathing losses. Boiling losses are defined as evaporation losses resulting from heating of the bulk liquid fuel to or above the temperature at which its vapor pressure is equal to atmospheric pressure. Since this condition is difficult to achieve in other than rather small tanks and in vented pipelines exposed to direct sun, it is not considered in this study. Working losses

are defined as those evaporation losses resulting from emptying and filling the tanks with consequent displacement of vapors into the atmosphere. These are sometimes called filling losses. Since filling losses are entirely a function of activity (i.e., use of POL), these losses are not considered either.

b. There remains a category of loss known as breathing loss. This type of loss results from changes in temperature of gases in the tank. (There is also a small component of breathing caused by changes in atmospheric pressure but breathing losses from this origin are negligible.) When the temperature increases, as during the day, the gases warm and flow out through the vent and, escaping into the atmosphere, are lost. Then, when the temperature declines, as at night, outside air flows back into the tank via the vent opening and mixes with the vapors inside the tank. While devices* are used to reduce breathing losses, these losses remain principally dependent upon temperature changes experienced by the gases inside the tank. These temperature changes arise from external ambient temperature change and from solar heat flux absorbed by external surfaces of the tank during the daytime. The temperature of the liquid contents of the tank changes but slowly owing to its much greater thermal inertia. In fact, the fuel acts in part to moderate the thermal effects transmitted through the upper surfaces of the tank. The color of these upper surfaces has a significant influence upon the amount of heat absorbed from solar radiation: light colors reflect the heat while dark colors absorb it. It was for this reason that past practice has been to paint the tanks white.

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* Such devices include pressure vents, inlet baffles, vapor conservation devices, floating roofs, and internal floating pans. All of the tanks considered have pressure vents and one has an internal floating pan.

c. The breathing loss (L) has been modeled (ref 2) by equation:

$$L = K_c k \left[\frac{P}{14.7-P}\right]^a D^b H^c T^d F$$

where

L = annual loss, bbl/yr

P = true vapor pressure, psia

D = tank diameter, ft

H = mean height of roof above fluid level (headspace), ft

T = mean daily ambient temperature change, °F

F = paint factor

K_c = fuel type adjustment factor

and

a,b,c,d,k = constants.

For determining the true vapor pressure P in cases where the mean fuel bulk temperature is not known, ref 2 states that this temperature is to be estimated by adding 5°F to the mean annual temperature. The mean daily ambient temperature change T is found by subtracting the mean daily temperature minimum from the mean daily temperature maximum. The paint factor F and the fuel type adjustment factor K_c are determined from field tests.

d. Ref 2 reports that this formula has been found to be reasonably accurate over a sufficiently long period of time* for tanks of more than 30 feet in diameter. (For a smaller tank, a correction factor must be

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* Wide divergences from the values predicted by this formula may be encountered over short periods of time. Over the space of a year, however, losses have been found to agree within ten percent.

applied. See Figure 1.) Values of the constants are given in ref 2 as follows:

$a = 0.68$

$b = 1.73$

$c = 0.51$

$d = 0.50$

$k = 0.024$

$K_c = 1.0$ for gasoline; 0.58 for crude oil.

e. A nomogram has been developed by API to simplify breathing loss calculations. A copy is appended hereto as Figure 2.

3. ASSUMPTIONS

a. It was assumed that camouflage paint has approximately the same infra-red reflectance characteristics as the "dark medium grey" paint which was evaluated in ref 2. This key assumption was considered reasonable since the tonedown paint has been specified only as "solid dull/flat colors." From Figure 3 it is seen that the paint factor could not increase by more than about 15 percent from the "dark medium grey" even if black paint were used. (See paragraph 6d).

b. In the absence of recorded data the annual mean fuel bulk temperature was considered to be 5°F greater than the annual mean atmospheric temperature. This is in accordance with the recommendations of ref 2.

c. Space above the fuel was assumed to average six feet. This assumption was based upon the PACAF "full tank policy" as moderated by the requirement to empty the tanks occasionally for maintenance and inspection. Losses are not particularly sensitive to changes in headspace. For example, the loss equation shows that increasing the mean headspace 100 percent increases the losses only by 40 percent.

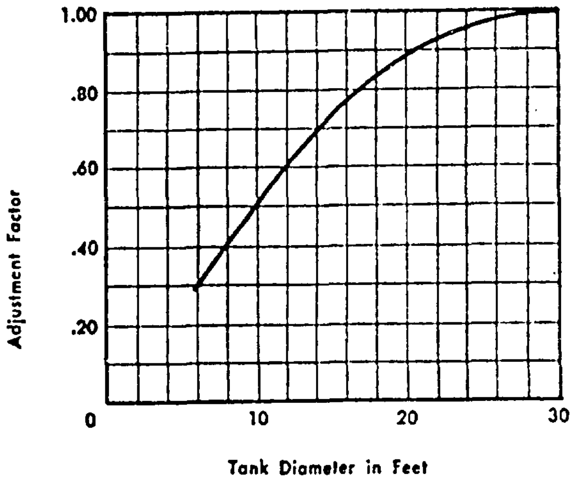

FIG. 1 —Adjustment Factor for Small-Diameter Tanks.

EXAMPLE:
T = 16°F
F_p = 1.33
H = 23 Feet
P = 5.8 psia
D = 100 Feet
L_y = 1350 barrels per year

Tank Color		Paint Factor, F_p	
Roof	Shell	Paint in Good Condition	Paint in Poor Condition
white	white	1.00	1.15
aluminum (specular)	white	1.04	1.18
white	aluminum (specular)	1.16	1.24
aluminum (specular)	aluminum (specular)	1.20	1.29
white	aluminum (diffuse)	1.30	1.38
aluminum (diffuse)	aluminum (diffuse)	1.39	1.46
white	gray	1.30	1.38
light gray	light gray	1.33	—
medium gray	medium gray	1.46	—

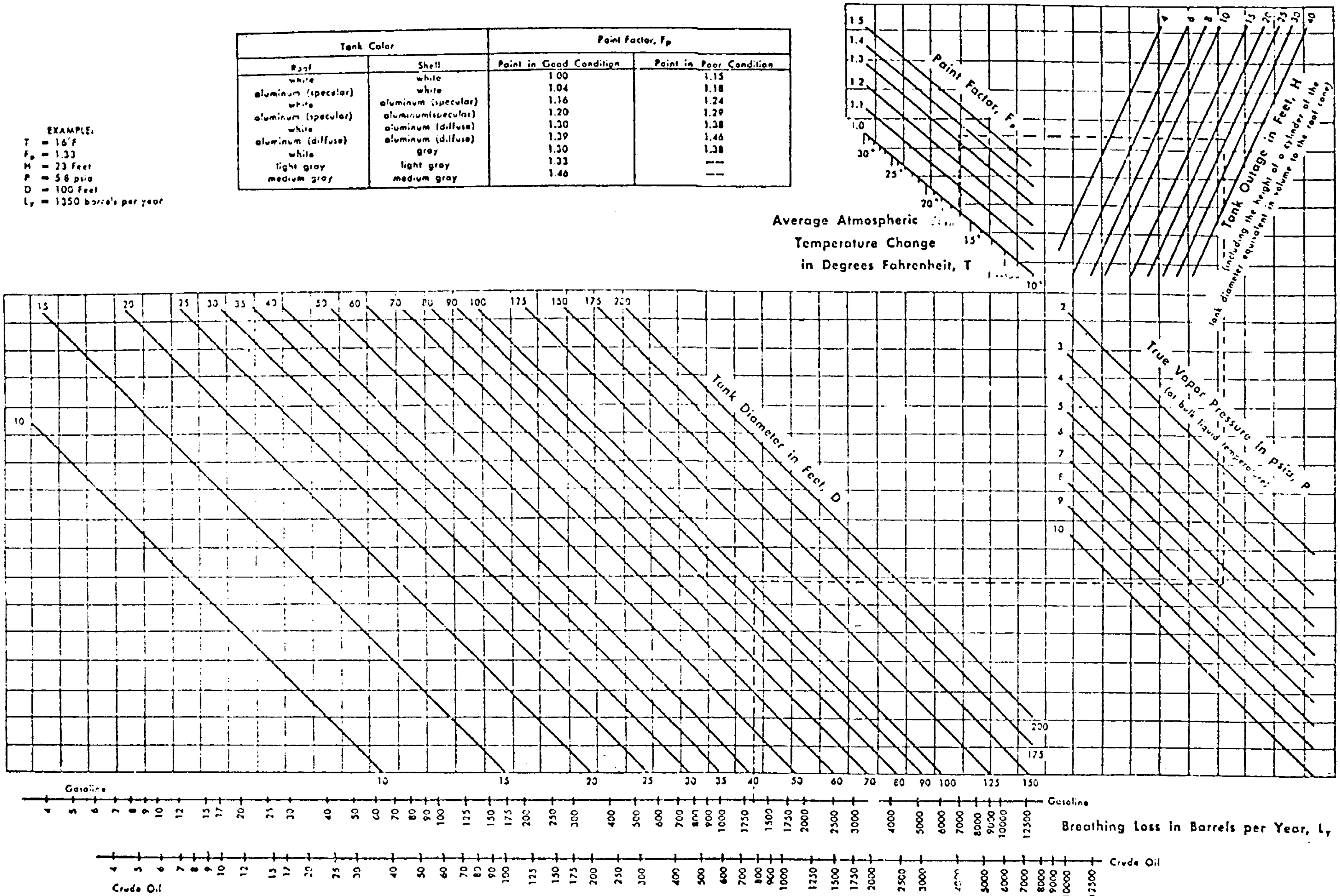

FIG. 2—Breathing Loss of Gasoline and Crude Oil from Fixed-Roof Tanks.

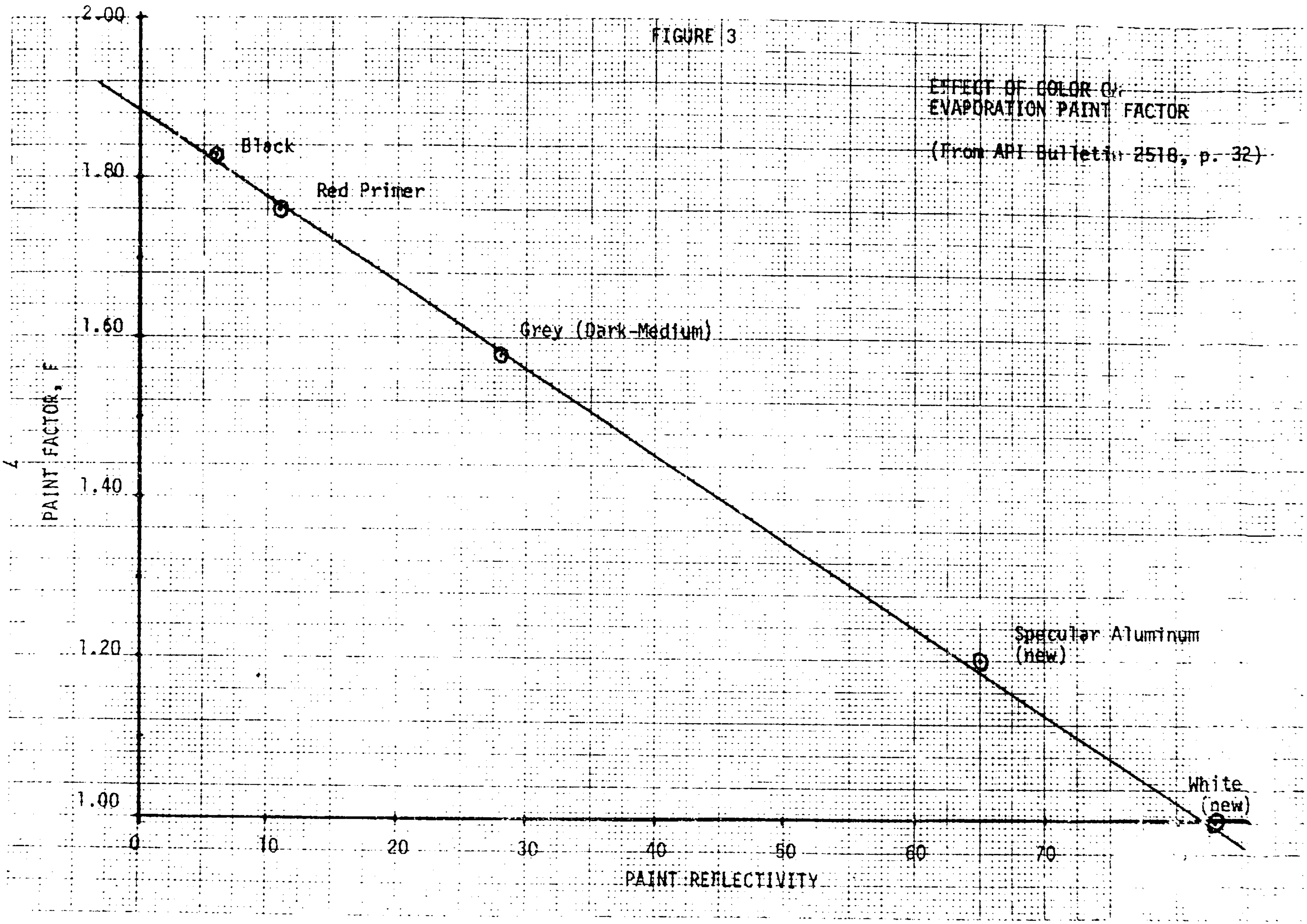

FIGURE 3

EFFECT OF COLOR ON
EVAPORATION PAINT FACTOR

(From API Bulletin 2518, p. 32)

d. Breathing losses from underground tanks were considered negligible, as were losses from smaller tanks (5,000 bbl and below). This is based upon the fact that underground and covered tanks are insulated from ambient temperature changes and so are not subject to significant daily breathing losses, while losses from smaller tanks are of considerably reduced significance when compared with losses from larger tanks as shown by the adjustment factor for small tanks in Figure 1.

e. Pressure/vacuum vents are set to operate at plus 2 1/2 oz per square inch pressure and minus 1/2 oz per square inch vacuum. At these settings the breathing losses are reduced by about 12 percent. (See Figure 6.)

f. Delivered fuel prices were taken to be $15 per bbl (35.7¢/gal) for the purpose of cost estimates.

g. In the absence of data, the volatility of diesel fuel was assumed similar to that of JP-4. This is because the K_c factor is reported in API publications only for gasoline and crude oil; this necessitates assuming JP-4 is more likely to have characteristics similar to crude oil rather than to gasoline.

h. Tanks which are being phased out in the very near future (six months) were not considered.

i. HQ PACAF (LGSF) values of Reid Vapor Pressures for the various fuels were used. These values tended to be higher than SOCAL data which would yield lower loss estimates.

4. DATA

a. Tanks. The 10,000 bbl tanks are approximately 55 feet in diameter. The 55,000 bbl tank being installed at Kunsan is 93 feet in diameter.

b. Fuel. Physical characteristics of fuels are summarized in Table 1 as follows:

TYPE FUEL	REID VAPOR PRESSURE	SLOPE OF ASTM EVAP CURVE AT 10% EVAP
JP-4	2.0 - 3.0	3.8
MG-1	7.0 - 9.0	2.5
115/145	7.5 - 8.0	2.7
DFM	UNKNOWN	UNKNOWN

Table 1. Fuel Characteristics

c. Climate.

(1) Annual mean daily temperature maxima are 61°F at Kunsan and 62°F at Osan.

(2) Annual mean daily temperature minima are 49°F at Kunsan and 44°F at Osan.

(3) Annual mean windspeeds are 8.1 mph at Kunsan and 5.2 mph at Osan.

5. CALCULATIONS

a. True Vapor Pressures (TVPs). Figures 4 and 5 are used to find the true vapor pressures, which are shown in Table 2.

Location	Mean Daily Temperature °F		Calculated Fuel Temperature °F (mean + 5°F)	Reid Vapor Pressure/Slope of ASTM Evap Curve at 10% Evap				True Vapor Pressure			
	High	Low		JP-4	MG-1	115/145	DF	JP-4	MG-1	115/145	DFM
Kunsan	61	49	60	$\frac{2.5}{3.8}$	$\frac{8.0}{2.5}$	$\frac{7.8}{2.7}$	*$\boxed{\frac{2.5}{3.8}}$	1.1	4.0	3.9	*(1.1)
Osan	62	44	58	$\frac{2.5}{3.8}$	$\frac{8.0}{2.5}$	$\frac{7.8}{2.7}$	*$\boxed{\frac{2.5}{3.8}}$	1.05	3.8	3.7	*(1.05)

* JP-4 data used for DFM

Table 2. True Vapor Pressures

b. Breathing Losses. Once the TVPs have been found, Figure 2 may be used to find breathing losses for fixed roof tanks without pressure vents

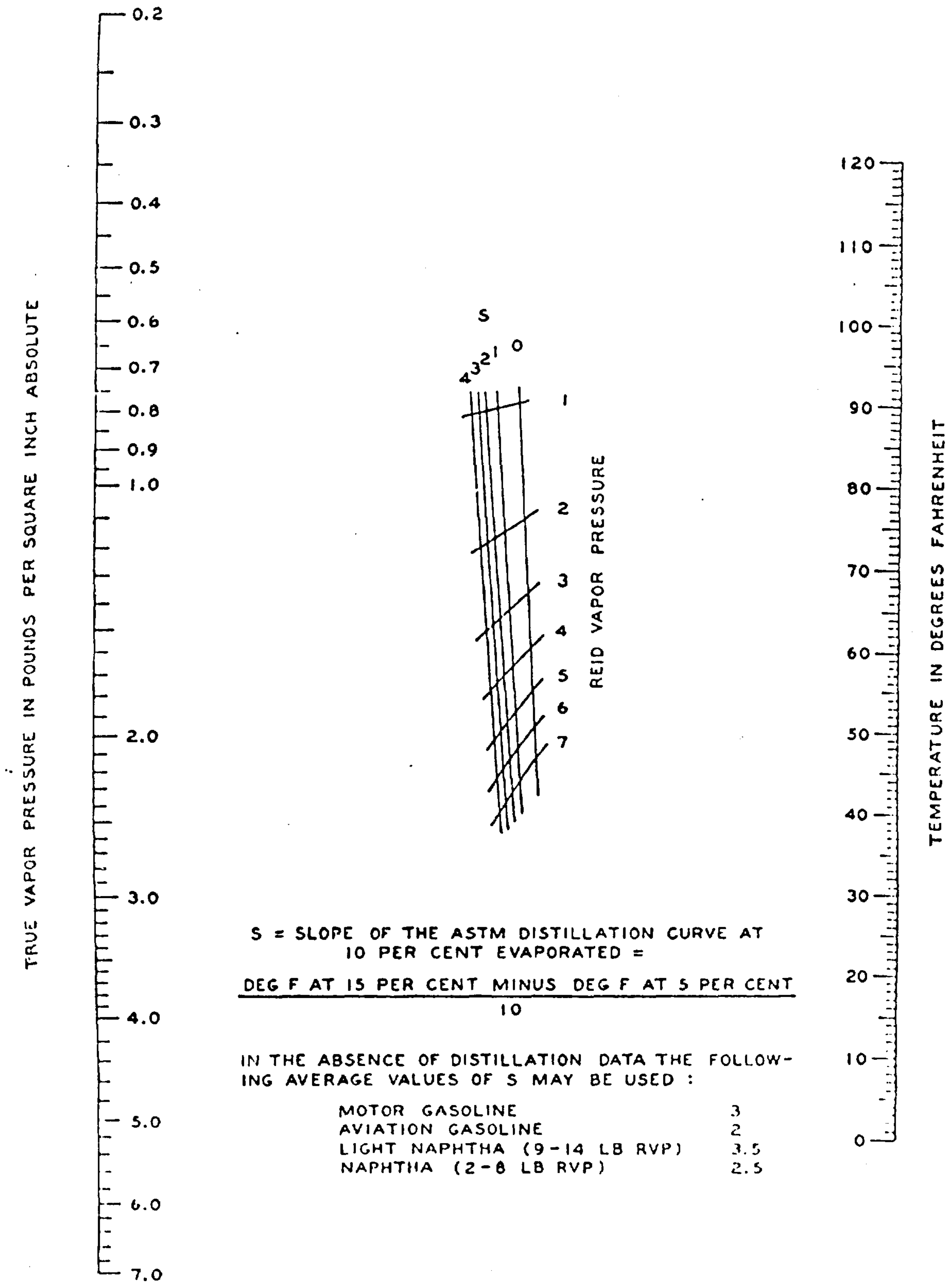

FIG. 4 —Vapor Pressures of Gasolines and Finished Petroleum Products—1 Lb to 7 Lb RVP.

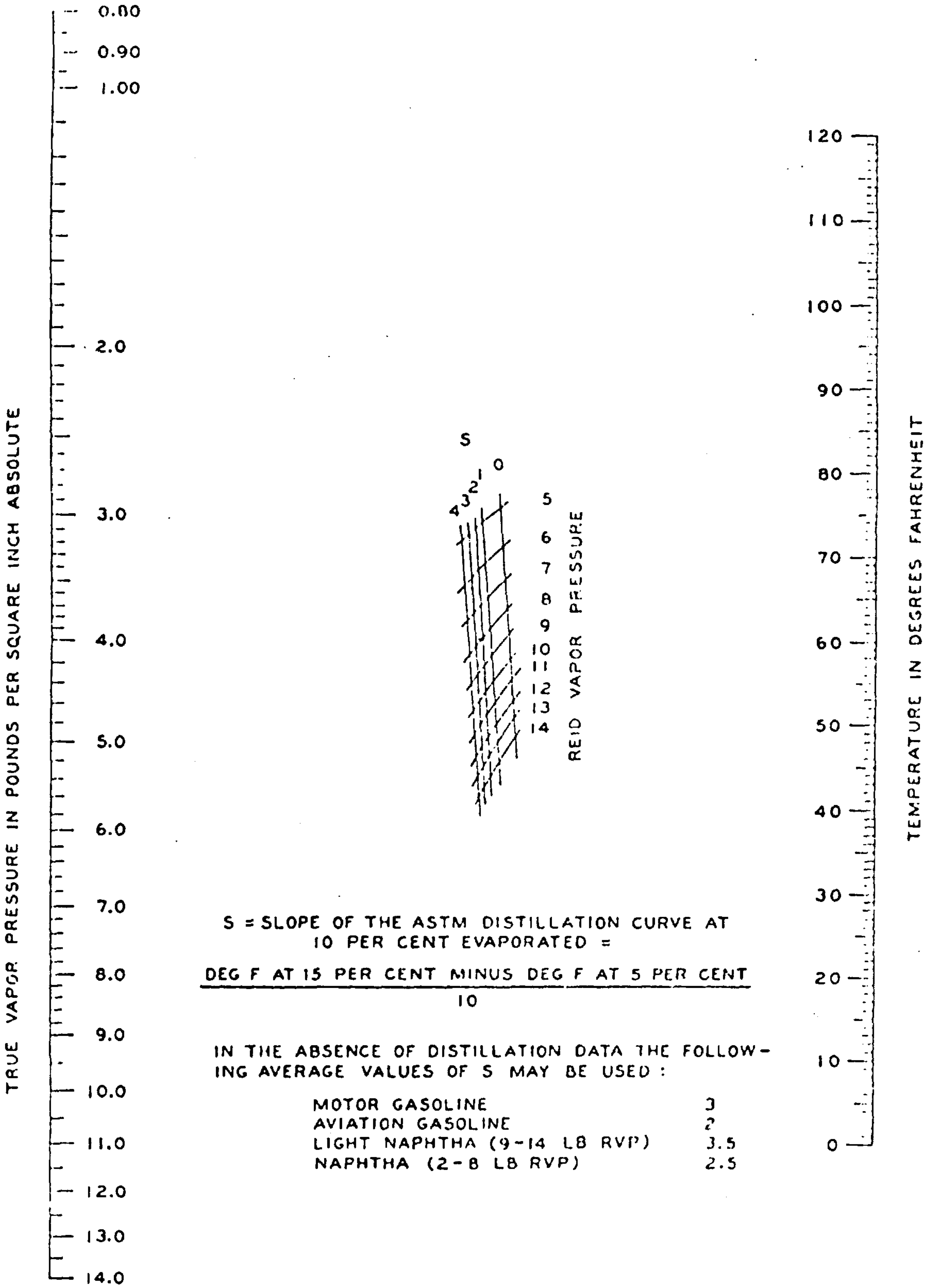

FIG. 5—Vapor Pressures of Gasolines and Finished Petroleum Products—5 Lb to 14 Lb RVP.

or floating pans. (The crude oil scale is used for JP-4 and diesel fuel, per paragraph 3g supra.) Values for losses of several fuels from 10,000 bbl tanks (55 ft diameter) and 55,000 bbl tanks (93 ft diameter), both painted white and toned down, are listed in Table 3.

Location	Tank Outage (Ft) (i.e. Headspace)	Mean Daily of Temp Change °F	Fuel	TVP	Losses[1] bbl/yr White F=1.00	Losses[1] bbl/yr Tonedown F=1.50	Losses[2] bbl/yr White F=1.00	Losses[2] bbl/yr Tonedown F=1.50
Kunsan	6	12	JP-4 MG-1 115/145 DFM	1.1 4.0 3.9 *(1.1)	25 105 100 25	35 160 155 35	60 260 245 60	90 390 385 90
Osan	6	18	JP-4 MG-1 115/145 DFM	1.05 3.8 3.7 *(1.05)	31 120 115 31	45 180 175 45	70 280 275 70	105 360 355 105

* JP-4 Data used for DFM

1 From 55' dia tanks (10,000 bbl)

2 From 93' dia tanks (55,000 bbl)

Table 3. POL Breathing Losses for Fixed Roof Tanks Without Pressure Vents or Floating Pans

c. Effects of Floating Pans. The 55,000 bbl tank is equipped with a floating pan. The procedure for calculating breathing losses from tanks with floating pans is given in reference 7. It is based upon the following empirical formula:

$$L_y = K_t D^{1.5} \left[\frac{P}{14.7-P}\right]^{0.7} V_w^{0.7} K_s K_e K_p$$

where:

L_y = evaporation loss -- bbl/yr

K_t = 0.045 to 0.14 depending upon tank type and seals. For welded tanks, the lower value is used

D = tank diameter -- ft

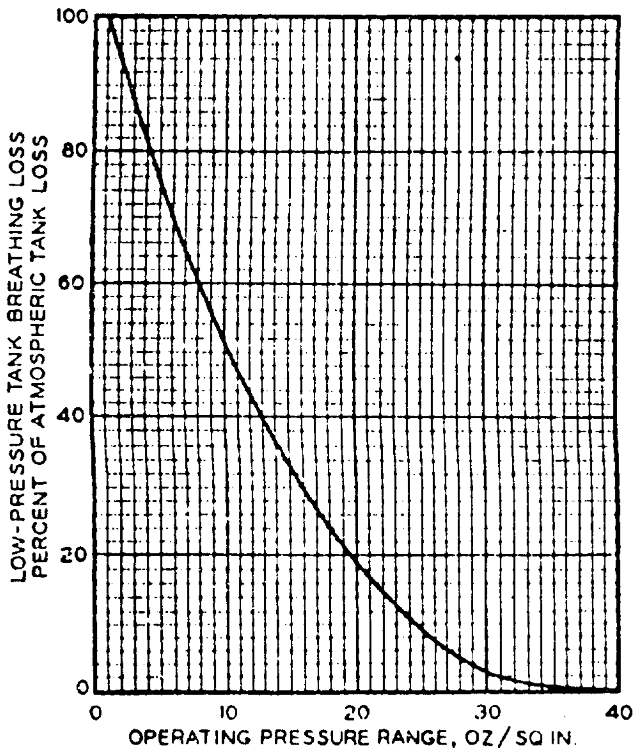

Figure 6. Relation for Estimating Breathing Loss From Tanks Operating at Less Than the 2.5 psi pressure vent setting. *

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* This curve is for motor gasoline only. It is suspected that pressure vents would be even more effective when used on tanks containing lower vapor-pressure fuels such as JP-4 and diesel fuel.

P = true vapor pressure of fluid in tank -- psia

V_w = mean wind speed -- mph

K_s = seal factor
= 1.00 for tight fitting seals
= 1.33 for loose fitting seals

K_c = fuel type factor
= 1.00 for gasoline
= 0.75 for crude oil

K_p = paint factor
= 1.00 for light grey or aluminum
= 0.90 for white

It is at once readily apparent that a wide range of values may be derived from this equation, depending upon the values selected for the numerous "constants." The paint factor to be used is obtained by extrapolation, using figure 7, to obtain a value equivalent to the paint factors used for fixed roof tanks. Since it is contemplated that this tank will be used for storage of JP-4, the true vapor pressure value used is P = 1.1 psia. Thus the equation reduces to:

$$L_y = K_t \times 93^{1.5} \left[\frac{1.1}{14.7-1.1}\right]^{0.7} \times 8.1^{0.7} K_s \times 0.75 \times K_p$$

$$= 500.323\ K_t\ K_s\ K_p$$

$$= 450.29\ (K_t\ K_s) \text{ for white paint}$$

$$= 525.34\ (K_t\ K_s) \text{ for tonedown}$$

The factor $(K_t\ K_s)$ ranges from 0.045 to 0.186, depending on type of tank and condition of floating pan seals. The annual loss, then, varies from $L_y = 20.26$ to $L_y = 83.75$ for white painted tanks and from $L_y = 23.64$ to $L_y = 97.71$ for toned down tanks. Since the tank at Kunsan is to be of welded construction, only values of $(K_t\ K_s)$ between 0.045 for tight seals and 0.060 for loose fitting seals should be considered. Thus L_y varies from 20.26 to 27.01 for white tanks of welded construction and from 23.64 to 31.52 for toned down tanks of

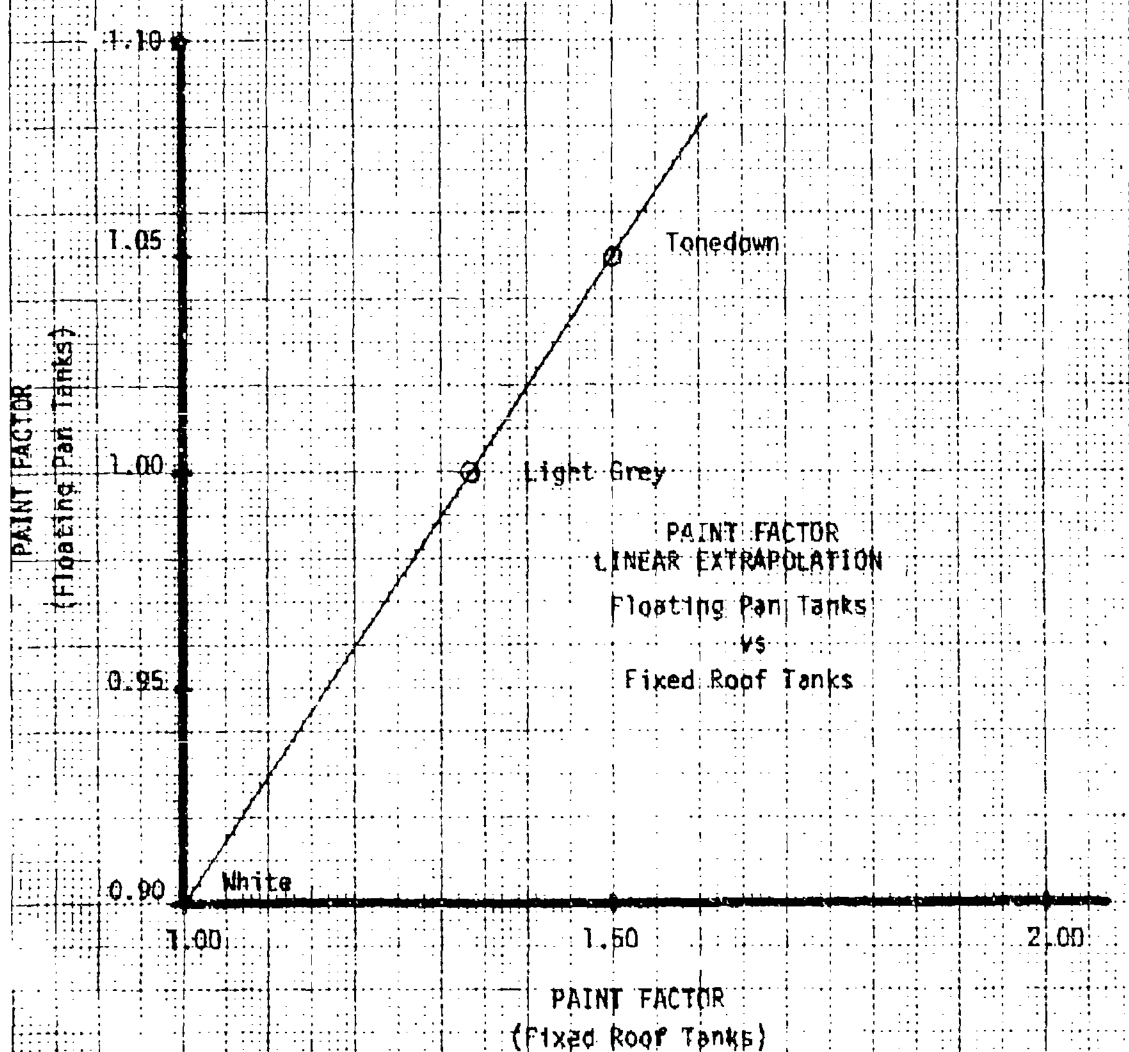

Figure 7. Linear Extrapolation of Paint Factors for Fixed Roof Tanks and for Floating Roof Tanks

welded construction. If the average of each of these pairs of values be used, then --

L_y = 23.6 bbl/yr for white tanks and,

L_y = 27.6 bbl/yr for toned down tanks.

From the foregoing it is seen that, except for tanks with floating pans, losses from tanks containing gasoline, either AVGAS or MOGAS, are about four times the losses from tanks containing JP-4 or diesel fuel, and that when the tanks are toned down the losses are increased by approximately 50 percent. Losses from tanks with floating pans are not only lower, but are much less sensitive to tonedown painting. Breathing losses from all tanks are reduced about 12 percent by the use of pressure vents per paragraph 3e supra. Values are summarized in Table 4.

5. DISCUSSION

a. After the present construction program is completed at Kunsan, only one above-ground tank is scheduled to remain operational. This tank is of 55,000 bbl capacity, will have a floating pan, and is planned to hold JP-4.

b. At Osan there are seven operational tanks of 10,000 bbl capacity. One of these tanks holds AVGAS. The other six contain either JP-4 or diesel fuel (which is treated like JP-4 in this paper).

c. The results of the previous section are summarized for these two locations as shown in Table 4.

d. If SOCAL physical characteristics were assumed for the fuels instead of the PACAF values used in this study, the values shown in Table 4 would be even smaller. On the other hand, if the tanks were painted flat black (the worst possible case) instead of the dark medium-grey color

assumed in this paper, the annual loss would be $\frac{1.83 - 1.58}{1.58} \times 100 \doteq 15$ percent greater (see Figure 3).

Location	Nr	Size	Contents	Total Annual Breathing Losses					
				Tonedown		White		Difference	
				bbl	$	bbl	$	bbl	$
Kunsan	1	55,000	JP-4	24	360	21	315	3	45
Osan	1	10,000	AVGAS	157	2255	103	1545	54	810
	6	10,000	JP-4/DF	243	3645	167	2505	76	1140
TOTAL ANNUAL BREATHING LOSS DUE TO TONEDOWN								133	1995

Table 4. Annual Breathing Losses

e. If POL tanks are to be camouflaged, three possible courses of action are, in increasing order of both camouflage effectiveness and cost:

(1) Repaint with tonedown colors

(2) Cover with camouflage netting

(3) Bury, either by mounding or in an excavation

This first course of action, painting, is beyond doubt the least costly of the three alternatives since the painting with tonedown colors will be accomplished in the normal course of the repainting cycle and will involve only the substitution of tonedown paint for white paint used heretofor. Evaporation losses are estimated at about $2000 per year more than losses with white paint. This averages out to only $250 per tank per year at current fuel prices.

f. While no cost estimates are available for coverage with netting, it is anticipated that both installation and maintenance costs will be substantial since it is necessary to erect supports to hold the netting well

above the roofs of the tanks in order to allow a working space between the canopy and the tanks themselves. This entails internal restructuring of the tanks because the tank roofs are not currently designed to support such loads. Netting does, however, provide excellent camouflage and tanks camouflaged by nets are not warmed by the sun, although their roofs and walls are exposed to the ambient heat of the day and cool of the night and so transmit this temperature change to the vapors within. This results in breathing, but it is less than for an exposed tank painted white and so is correspondingly less yet than for a tank painted with tonedown colors and exposed to the warming solar rays. How much less is not known, but it is surely somewhere between the $800 per tank per year that would be saved by burying the tanks and the $250 that would be saved by leaving them white. On the other hand the cost of suspending wire netting above the tanks, while less than the cost of burying the tanks, is clearly greater than the cost of repainting them in tonedown colors, for repainting comes virtually free of additional costs since it is to be done during the normal cyclic repainting schedule.

g. Burying tanks is more expensive than erecting poles and covering them with netting. In this case the tanks must be reinforced to prevent collapse of the sidewalls when the tank is empty. And the roof must be strengthened to support the overburden of earth. A single 10,000 bbl tank costs $73,000 more if it is buried. But, underground, there would be no reduction in breathing losses from a floating pan. As seen from Table 5, the cost saved by omitting the floating pan is $32,400. Furthermore, buried tanks do not require protective ring walls; only direct hits are likely to damage underground tanks; and once damaged, the inflammable contents are safely contained by the earth itself. Since a typical protective ring wall for a 10,000 bbl tank in Korea costs in the neighborhood of $72,000, the net saving is

$$\$32,400 + \$72,000 - \$73,000 = \$31,400$$

Type of Tank	Cost of Tank 1/	Cost Ring Wall 2/	Total Cost of Tank
10,000 bbl Above Ground	$108,000	$72,000	$180,000
10,000 bbl Above Ground with Pan	$140,400	$72,000	$212,400
10,000 bbl Buried	$181,000	Not Req'd	$181,000
55,000 bbl Above Ground	$306,900	$205,000	$511,900
55,000 bbl Above Ground with Pan	$524,700	$205,000	$729,700
55,000 bbl Buried	$739,200	Not Req'd	$739,200

Source: 1. Reference 9.
2. CINCPACAF/DE estimate.

Table 5. Costs of Tank Installations in Korea

which makes underground tanks very attractive in terms of current policy which prescribes floating pans for aboveground tanks. But, as shall be seen in paragraph 6h, infra, floating pans are uneconomical and never pay for themselves, even in tanks containing gasoline, as long as the "full tank policy" is followed. Thus buried tanks, as compared with aboveground tanks without floating pans, do not provide significant savings. Furthermore, maintenance is a problem because earth must be removed to effect repairs. But there is considerable attraction in the far superior protection offered: with vegetation covering the soil over the tank, camouflage can be very good indeed; only direct hits are likely to damage buried tanks; and once damaged, the inflammable contents are safely contained by the earth itself. Underground tanks suffer virtually no daily breathing losses, for the warmth of the day and the rays of the sun never penetrate to the region occupied by the vapors between the upper surface of the fuel and the roof of the tank, so that the temperature within the tank remains virtually constant over any twenty-four hour period and varies but slowly from season to season. But not all soils are suitable for burying tanks. And high water-tables can present a problem in keeping tanks buried: the tanks tend to float up out of the earth. Nor are suitable locations always available on the crowded air bases in Korea. But where tanks are placed underground, evaporation savings can be as high as $2255 per year for a toned down 10,000 bbl tank of gasoline without a pan, and $600 per year for the same tank with JP-4 in it. Over the 30-year life of a tank, these savings are not insignificant. But where there is an option of storing either gasoline or JP-4 in an underground tank -- all else being equal -- the choice is clear: store the gasoline below ground to reduce evaporation losses. The improved safety factor in placing this more volatile substance below ground is also abundantly clear. Likewise, where there is an option of storing gasoline or JP-4 in a tank equipped with a floating pan, the gasoline should be stored in the tank with the floating pan.

h. From Table 5, it is seen that the cost of a floating pan in a 10,000 bbl tank is approximately $32,400.* How long would it take to pay off this investment? To make this calculation, the cost C of the pan over a period of n years, neglecting maintenance costs (which may not be small, especially if the pan sinks, but are difficult to estimate), is taken as

$$C = P\,(1 + r)^n$$

where P = initial cost

r = interest rate

This cost is to be offset against the savings S in cost of fuel saved over the same period of n years

$$S = L\,\frac{(1 + r)^n - 1}{r}$$

where L = annual cost of fuel loss.

C is set equal to S and the resulting equation is solved for n

$$P\,(1 + r)^n = L\,\frac{(1 + r)^n - 1}{r}$$

$$(1 + r)^n\,\left(\frac{L}{r} - P\right) = \frac{L}{r}$$

$$(1 + r)^n = \frac{L}{L - rP}$$

taking logarithms of each side

$$n \,\mathrm{Log}\,(1 + r) = \mathrm{Log}\,\left(\frac{L}{L - rP}\right)$$

$$n = \frac{\mathrm{Log}\,\left(\frac{L}{L - rP}\right)}{\mathrm{Log}\,(1 + r)}$$

The annual evaporation loss of gasoline from a toned down, welded, 10,000 bbl tank at Osan, equipped with a floating pan is (per paragraph 5b, supra)

* Civil Engineering cautions that this is a rough estimate. The cost would be less as an increment in the purchase and erection cost of a new prefabricated tank.

$$L_y = K_t \times 55^{1.5} \left[\frac{3.8}{14.7 - 3.8}\right]^{0.7} 5.2^{0.7} K_s \times 1.00 \times 1.05$$

$$= 653.71 \; (K_t \; K_s)$$

$$= 29.4 \text{ to } 39.2 \approx 34.3 \text{ bbl/yr}$$

$$\doteq \$514/\text{yr} \;\; @ \;\; \$15/\text{bbl}$$

which is to be reduced by 12 percent to account for savings resulting from pressure/vacuum vent. This leaves a value of

$$L_y \approx \$437/\text{yr}$$

To find the savings owing to use of a floating pan, then, this value is subtracted from \$2255, the annual loss from the same tank without a floating pan.

$$L = \$2255 - \$437 = \$1818/\text{yr}$$

If, also, $r = 8\%$ per annum

$P = \$32,400$

then

$$n = \frac{\text{Log}\left(\frac{L}{L - rP}\right)}{\text{Log}\,(1 + r)}$$

$$= \frac{\text{Log}\left(\frac{1818}{1818 - 2592}\right)}{\text{Log } 1.08}$$

$$= \frac{\text{Log } -2.35}{\text{Log } 1.08}$$

= more than an infinite number of years*

From this it can be seen that a floating pan can never pay for itself under these circumstances. (But if the "full tank policy" were not followed, increased losses might justify floating pans.)

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* The maximum initial cost which can ever be paid off is $P = \frac{L}{r} = \frac{1818}{.08} =$ \$22,725. (And even this would require an infinite number of years.)

i. Although working losses are not the proper subject of this report, they cannot be divorced from any recommendation to dispense with the floating pan. Paragraph 6h, supra, has set forth reasoning which shows that floating pans cannot be justified by benefits accruing from a reduction in breathing loss from tanks which are kept relatively full (the PACAF "full tank policy"). Whether this be true or not of tanks remaining relatively empty is moot since such a state would be a violation of policy. On the other hand, what about tanks which are worked significantly? Reference 7 states that withdrawal loss from tanks equipped with floating pans is negligible, while reference 2 sets forth the formula for the loss from one filling to the next as

$$L = 3PVK_t \times 10^{-4}$$

where: P = true vapor pressure of fuel

V = volume of fuel pumped

$K_t = (180 + N)/6N$

where: N = annual thruput divided by tank capacity

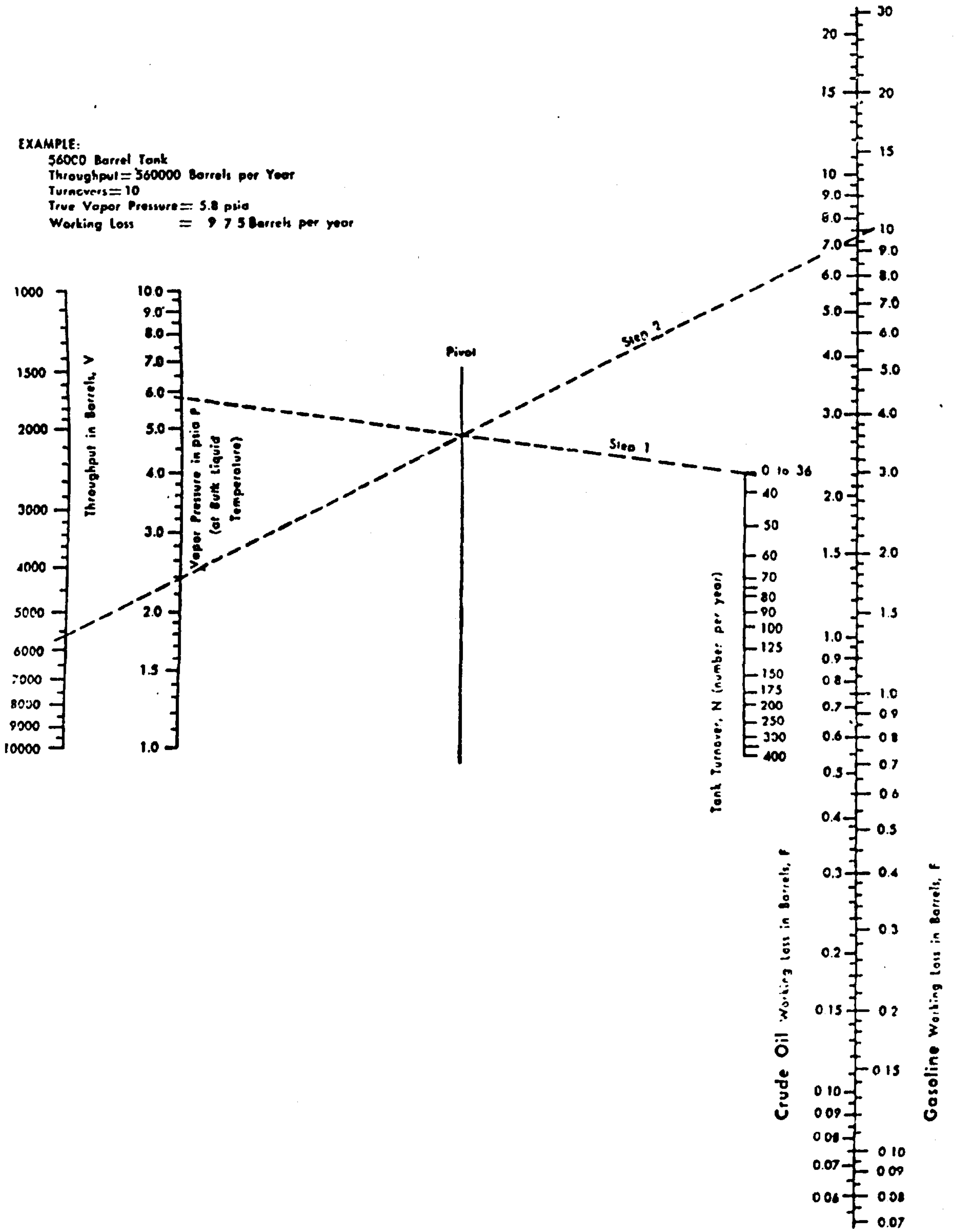
The factor K_t is considered unity for less than 37 turnovers per annum. Thus a 10,000 bbl tank of AVGAS at Osan with 10 turnovers per year would suffer an annual working loss of

$$L_y = 3 \times 3.7 \times 10 \times 10{,}000 \times 1.0 \times 10^{-4}$$

$$= 101 \text{ bbl/year}$$

$$= \$1515\text{/year.}$$

Since most of this would be saved by a floating pan, the annual savings of \$1515 +\$1818 = \$4343 indicate that a pan would, under these conditions, pay for itself in



Note:

The throughput is divided by a number (1, 10, 100, 1,000) to bring it into the range of the scale. The working loss, read from the scale, must then be multiplied by the same number.

FIG. 8 —Working Loss of Gasoline and Crude Oil from Fixed-Roof Tanks.

$$n = \frac{\text{Log}\left(\frac{4343}{4343 - 2592}\right)}{\text{Log } 1.08}$$

$$= \frac{\text{Log } 2.48}{\text{Log } 1.08} = \frac{0.394503}{0.033424}$$

$$= 11.8 \text{ years}$$

Thus it is seen that the decision whether to install a floating pan or not depends to a very large degree upon thruput. Where use is made of smaller tanks -- especially bladder tanks -- for working storage, larger tanks being kept full, it is clear that floating pans cannot be justified even for gasoline storage. It is likewise clear that floating pans cannot be justified for JP-4 storage irrespective of how the tank is worked.

7. CONCLUSIONS

a. Evaporation breathing losses resulting from camouflaging POL tanks with tonedown paint on US air bases in Korea should not exceed about $2000 per year, at present costs of $15 per barrel in place.

b. If tanks are buried instead of toned down, total savings of up to $6200 per year in evaporation losses may be realized over toning down the tanks, and increased protection will result. But not all locations are suitable for burying tanks, although net costs are about the same for aboveground and for underground POL tanks.

c. If tanks are camouflaged with netting, evaporation losses will be between present losses with white tanks and losses expected with buried tanks; an evaporation loss saving over current practice and an even greater saving over proposed tonedown painting. Netting installations, however, introduce problems of handling, maintenance, accessibility, etc. These factors are to be balanced against the better concealment afforded by netting.

8. RECOMMENDATIONS

a. The present policy of burying tanks where possible should be continued. Burying results in maximum concealment, maximum protection, and minimum evaporation losses.

b. The more volatile fuels, AVGAS and MOGAS, should be given priority for underground storage to reduce evaporation losses and keep safety hazards at a minimum. Where underground storage is not available, these fuels should be stored in tanks with floating pans or with other means of evaporation loss reduction.

c. Aboveground POL tanks may be camouflaged by painting them with tonedown colors. Where AVGAS or MOGAS is stored aboveground, some consideration should be given to the superior concealment obtainable with permanent type wire netting because of the reduction in breathing losses afforded.

d. The full tank policy of Hq PACAF should be continued since this results in minimum breathing losses.

e. If construction requirements dictate that more aboveground tanks are to be installed in Korea, they should be equipped with floating pans only under special circumstances.

f. Small working tanks, preferably bladder tanks, may be used to reduce working losses to a minimum.

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9. Cost Guidance for FY 76, Hq USAF/PRE

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